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Project 1
BME 471: Bioelectric Phenomenon

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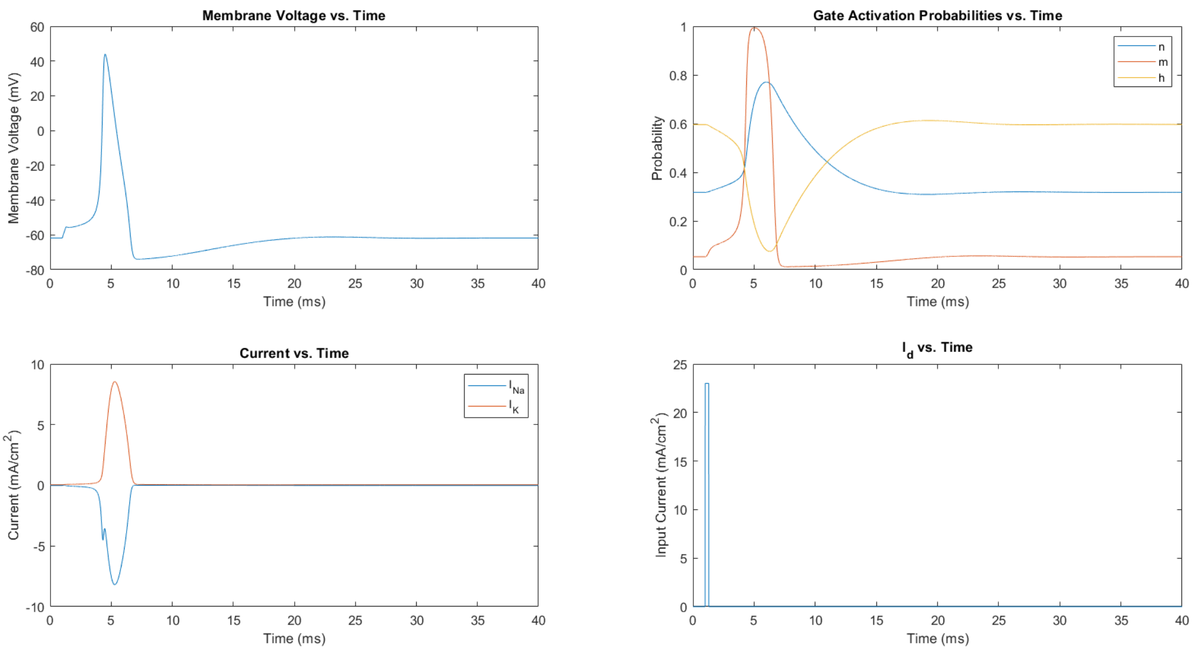
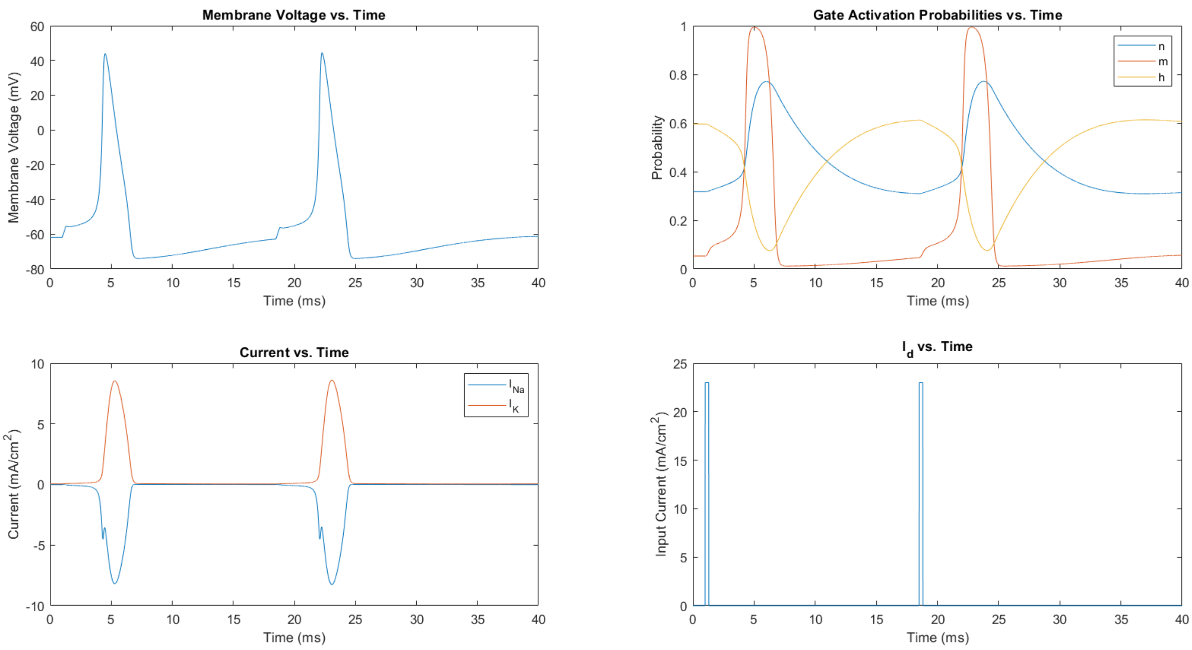
Depolarization

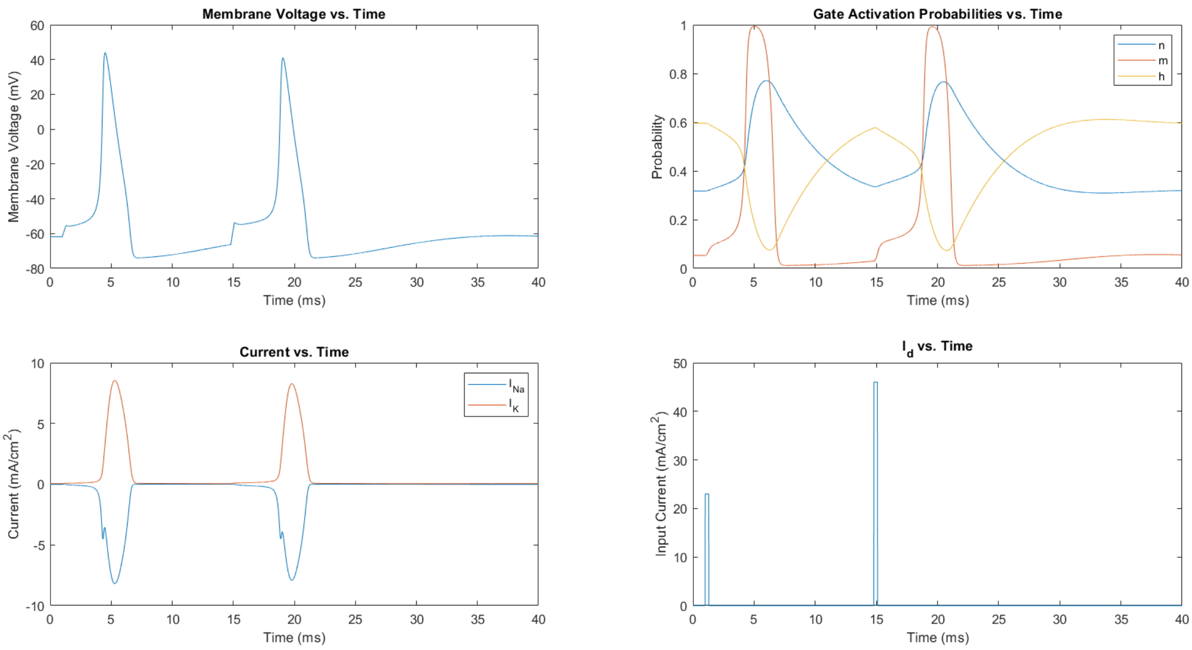
It was found that an amplitude of $\boxed{I_d = 23mA/cm^2}$ for a 0.3 ms square wave was necessary to initiate an action potential. The plots below show the systems response to this stimulus



In order to initiate another action potential, it was found that a delay of $\boxed{17.5 \text{ ms}}$ was needed at the same amplitude. The plots below showcase this

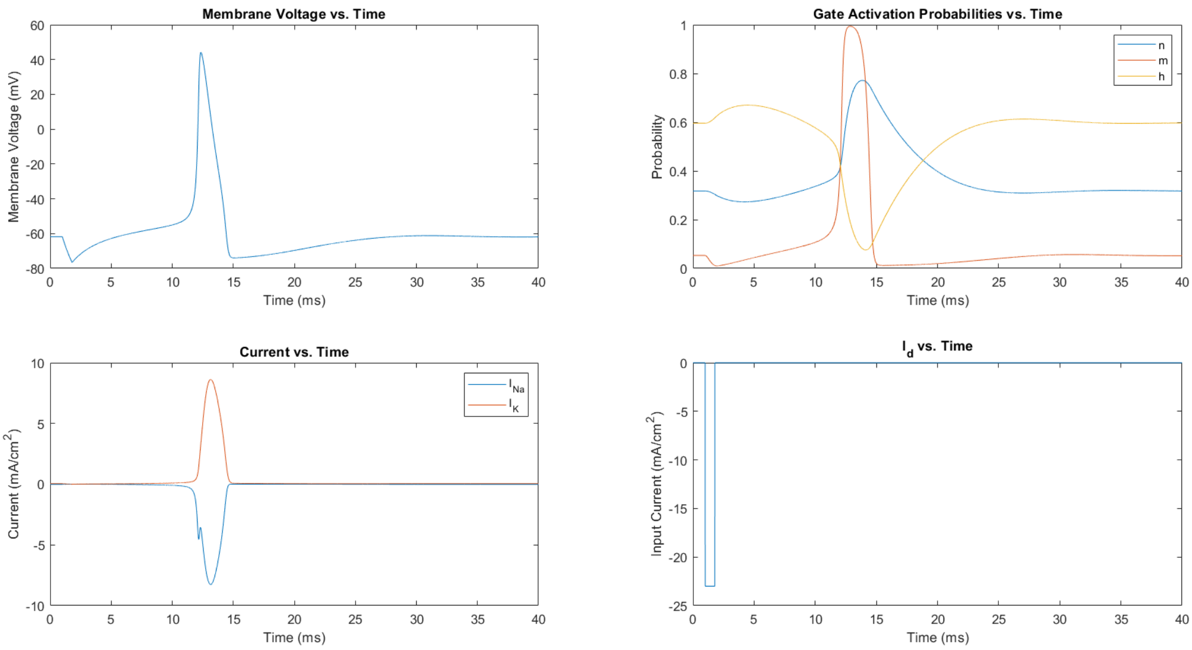


If the amplitude was doubled to 46 mA/cm^2 it was found that the necessary delay was only $\boxed{13.8 \text{ ms}}$ as seen below



Hyperpolarization

In order to trigger an anode-break initiation of an action potential a stimulus current of -23 mA/cm^2 was applied for $\boxed{0.8 \text{ ms}}$. The plots below show how the system responded to this stimlus.



Code

```
%% Initial Conditons
y0(1,1) =  -61.7987;          % V0
y0(2,1) = 0.317671;               % n0
y0(3,1) = 0.0529322;             % m0
y0(4,1) = 0.596147;               % h0
%% Input Current
TFinal = 40;
t0 = 1; t1 = t0 + 0.8;
%t2 = t0 + 12.5; t3 = t2 + 0.3;
IMag = 23;
IMag = -IMag;
%IMag = IMag * 2;
Idt = 0:0.001:TFinal;
Id = zeros(length(Idt),1);
Id(Idt >= t0) = IMag;
Id(Idt >= t1) = 0;
%Id(Idt >= t2) = IMag;
%Id(Idt >= t3) = 0;

%% ODE45
dt=[0,TFinal]; % time of integration in ms
options=odeset('RelTol',1e-4,'AbsTol',[1e-8 1e-8 1e-8 1e-8],'MaxStep',0.01);
[t,y]=ode45(@(t, y) hh_diff_eq(t,y,Id,Idt, y0(1,1)), dt, y0, options);
V = y(:,1); n = y(:,2); m = y(:,3); h = y(:,4);

%% Find Conductances as a Function of Time
gNABar = 120; gKBar = 36;
gK = gKBar.*n.^4;
gNA = gNABar.*m.^3.*h;

%% Find Currents as a Function of Time
% Max Extracellular Concentration (mmol/L)
ECNA = 490; ECK = 20;
% Max Intracellular Concentration (mmol/L)
ICNA = 50; ICK = 400;
% Na and K Potentials
ENA = 25*log(ECNA/ICNA); EK = 25*log(ECK/ICK);
% Current
INA = gNA.*(V - ENA);
IK = gK.*(V - EK);


%% Plot Results
figure()
subplot(2,2,1)
plot(t,V);
title("Membrane Voltage vs. Time")
xlabel("Time (ms)")
ylabel("Membrane Voltage (mV)")

subplot(2,2,2)
plot(t,n);
hold on
plot(t,m);
plot(t,h);
title("Gate Activation Probabilities vs. Time")
xlabel("Time (ms)")
ylabel("Probability")
legend(["n" "m" "h"])

subplot(2,2,3)
plot(t,INA * 10e-3);
hold on
plot(t,IK * 10e-3);
title("Current vs. Time")
xlabel("Time (ms)")
ylabel("Current (mA/cm^2)")
legend(["I_{Na}" "I_K"])

subplot(2,2,4)
plot(Idt,Id);
title("I_d vs. Time")
xlabel("Time (ms)")
```

```
ylabel("Input Current (mA/cm^2)")


function dy = hh_diff_eq(t,y, U, Ut, Vrest)
    %% Set Up
    Id = interp1(Ut, U, t);
    % Assign Input Parameters
    V=y(1,1); n=y(2,1); m=y(3,1); h=y(4,1);
    % Max Conductances (mS/cm2)
    gNABar = 120; gKBar = 36; gLeak = 0.3;
    % Max Extracellular Concentration (mmol/L)
    ECNA = 490; ECK = 20;
    % Max Intracellular Concentration (mmol/L)
    ICNA = 50; ICK = 400;
    % Na and K Potentials
    ENA = 25*log(ECNA/ICNA); EK = 25*log(ECK/ICK);
    % Leak Nernst Potential (mV)
    EL = -50;
    % Membrane Capacitance (uF/cm2)
    Cm = 1;
    % vm = Vm - Vrest
    vm = V - Vrest;
    %% Alphas and Betas
    alphan = (0.01*(10-vm))/(exp((10-vm)/10) - 1);
    betan = 0.125*exp(-vm/80);
    alpham = (0.1*(25-vm))/(exp((25-vm)/10) - 1);
    betam = 4*exp(-vm/18);
    alphah = 0.07*exp(-vm/20);
    betah = 1/(exp((30-vm)/10) + 1);
    %% Differential Equations
    dv = (1/Cm)*(Id - gNABar*m^3*h*(V-ENA) - gKBar*n^4*(V-EK) - gLeak*(V-EL));
    dm = (-1*(alpham + betam)*m + alpham);
    dn = (-1*(alphan + betan)*n + alphan);
    dh = (-1*(alphah + betah)*h + alphah);

    dy = [dv; dn; dm; dh];


end
```